CMG-5TD Digital Accelerometer

Operator's Guide

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1 Preliminary Notes

1.1 Proprietary Notice

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1.2 Warnings, Cautions and Notes

Warnings, cautions and notes are displayed and defined as follows:

HARMFUL	**Warning:** A black cross indicates a chance of injury or death if the warning is not heeded.

	Caution: A yellow triangle indicates a chance of damage to or failure of the equipment if the caution is not heeded.

	Note: A blue circle indicates indicates a procedural or advisory note.

1.3 Manuals and Software

All manuals and software referred to in this document are available from the Güralp Systems website, www.guralp.com, unless otherwise stated.

1.4 Conventions

Throughout this manual, examples are given of command-line interactions. In these examples, a fixed-width typeface will be used:

`Example of the fixed-width typeface used.`

Commands that you are required to type will be shown in bold:

`Example of the fixed-width, bold typeface.`

Where data that you type may vary depending on your individual configuration, such as parameters to commands, these data are additionally shown in italics:

`Example of the fixed-width, bold, italic typeface.`

Putting these together into a single example:

`System prompt:` **`user input with`** ***`variable parameters`***

2 Introduction

The CMG-5TD consists of a fully-integrated triaxial accelerometer (CMG-5T) and a matched 24-bit digitizer (DM-24) contained in a single, watertight package. It is compact, lightweight, and simple to deploy. It can resolve the full range of acceleration due to microearthquakes (0.1 uG resolution) up to strong local earthquakes (4 g resolution).

It is provided with a combination baseplate/mounting plate, which is separable and re-attachable, allowing for quick installation/removal and sensor site re-occupation if necessary. The DC offsets are available at the analogue output connector of the CMG-5TD and are user-accessible and adjustable via adjusting screws on the top cap of the instrument. A GPS receiver is used to provide accurate time-stamps for seismic data. The GPS receiver is attached to the CMG-5TD via a supplied 20 metre cable.

3 Quick start

3.1 Unpacking and packing

The CMG-5TD accelerometer system is delivered in a single cardboard box with foam rubber lining. The packaging is specifically designed for the CMG-5T system. Whenever transported, the CMG-5TD system should be packed in its original shipping container. The packaging should be saved for re-use in the event of a later shipment.

Upon receipt of the equipment, please note any damage to the package. Unpack on a clean surface. The package should contain: digital accelerometer, a separable levelling baseplate, baseplate screws, concrete anchor and mounting bolt, GPS receiver, GPS receiver cable and power/data connection cable.

Place the CMG-5TD on a table and identify

- The power/data cable connector on the CMG-5TD top cap.
- The GPS cable connector on the CMG-5TD top cap.
- The analogue connector on the CMG-5TD top cap.
- The north orientation symbol on the CMG-5TD handle.
- The bubble level on the CMG-5TD top cap

- The screw on/off cover for output offset adjustment on the CMG-5TD top cap.
- The serial number on the label, on the top or side of the instrument.

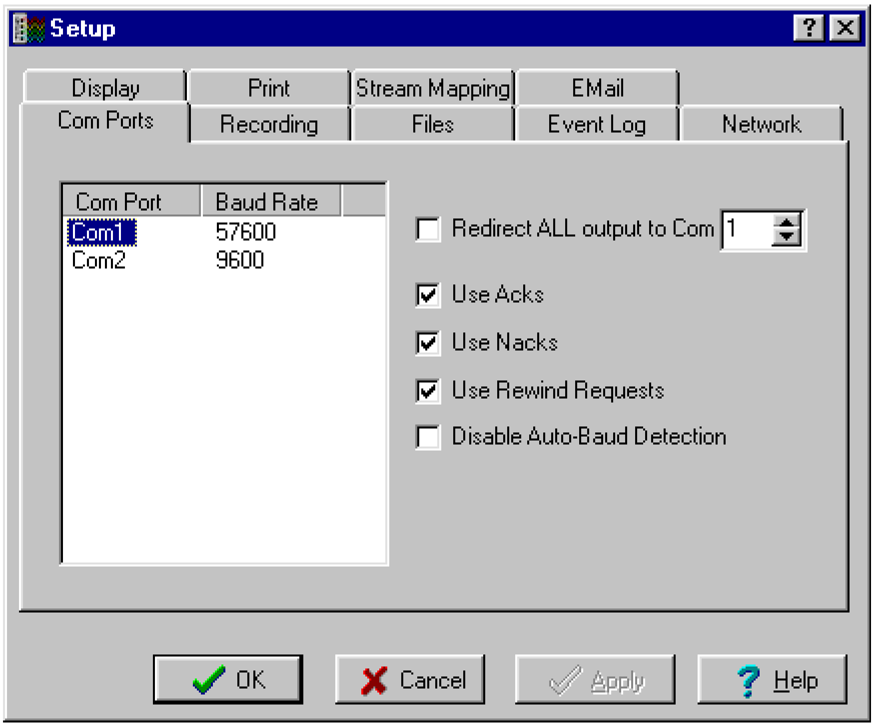
3.2 Initial check-out

This section gives a quick outline for initial system test, which should performed prior to installation. You must provide 10-36 V DC power and a PC running Scream.

Attach the levelling baseplate to the base of the CMG-5TD using the screws provided. Set the CMG-5TD onto a flat surface. Using the large hex screws on the baseplate in conjunction with the bubble level, level the instrument. Connect the CMG-5TD directly to the PC using the supplied power/data cable

Switch on the power supply. Using the PC, start Scream and take the following steps:

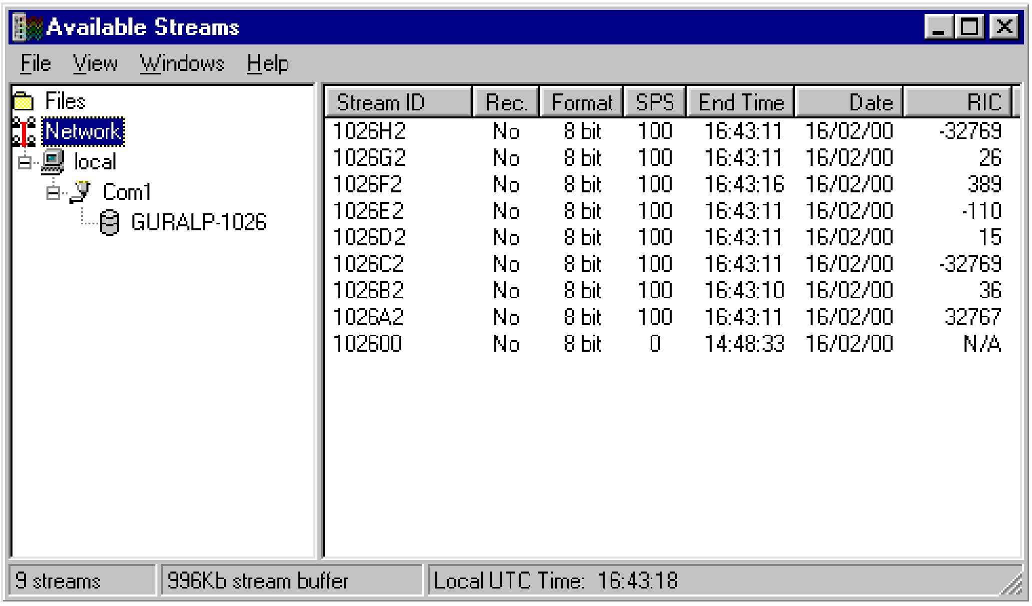
1. Click on 'Setup', from the 'File' menu



2. Select the 'Com Ports' tab
3. Click on the COM port to which the instrument is connected.
4. The factory-set baud rate for the CMG-5TD is 19200. Select 19200 from the list.
5. Click on the 'OK' button to return to the main Available Streams window.

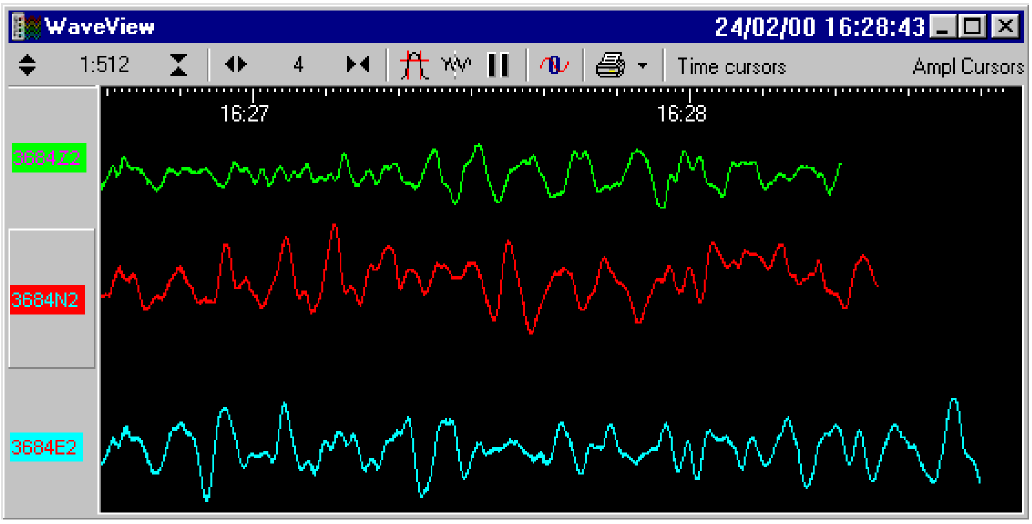
6. In the Available Streams window, the identifier of the instrument will appear in the left hand frame (which appears similar to the tree type format of Windows Explorer) under Network → Local → Com1' (if Com1 is used)

7. The data streams will appear in the right-hand frame.



8. The Stream IDs are six-character strings which uniquely identify each instrument, component and sample rate. (There may be up-to four different sample rates per channel) The stream ending in '00' contains status information from the digitiser. Streams with higher sample rates will appear in the display sooner than the slower sample rates and it might take several minutes for the status stream to appear.

9. Select the data streams in the right side of the window by clicking on the first and then control-clicking on the last. Press the "ENTER" key to open these streams in a new 'Waveview' window.



10. To see status information coming from the digitiser, right click on the status stream. From the pop-up menu, select 'View'. A new window, 'Status' should open containing text. The first blocks will give the boot message from the DM, including its software revision and the data streams selected for down-loading and triggering. Later blocks give information on the expected GPS satellites, the location of the GPS antenna, time synchronization status and transmit/receive baud rates for each channel and the data link.

11. While viewing the time series from all three components in a WaveView window, gently tap the CMG-5TD, and observe the response of all three components. If the CMG-5TD passes this initial basic test, then you may proceed to install the system (see the Operation section of this User's Guide).

4 Setting the gain

The built in 5T sensor has a very large dynamic range. In order to exploit the whole of this range, two separate outputs are available, one with high gain and one with low gain. Normally, the high gain outputs are set to output a signal 10 times stronger than that from the low gain outputs. Only one set of outputs – low gain or high gain – is sent to the digitiser; the selection of which output to digitise is made using internal jumpers.

Note: To change the gain, it is necessary to open the instrument. This work must be carried out in a clean environment in order to prevent contamination of the mechanical components by air-borne dust.

Caution: The CMG-5TD include components which can be damaged by electrostatic discharge (ESD). Always work on a properly grounded dissipative surface and wear a suitable grounded wristband. Ground yourself by touching an earthed conductor before handling any of the circuit boards.

4.1 Disassembly

In order to change the gain-setting jumpers, remove the instrument's lid as follows:

- Use a large, flat-bladed screwdriver to remove the pressure-release screw located on the instrument's lid next to the bubble-level.

  Warning: GSL instruments are assembled at near to sea level. When using the instrument at altitude, there may be a considerable pressure differential between the air inside the casing and the external atmosphere. This could cause the screw to fly off with considerable force when initially released. Take care that this does not cause injury.

- Use a small, flat-bladed screwdriver to remove the six small screws located around the edge of the top of the lid.

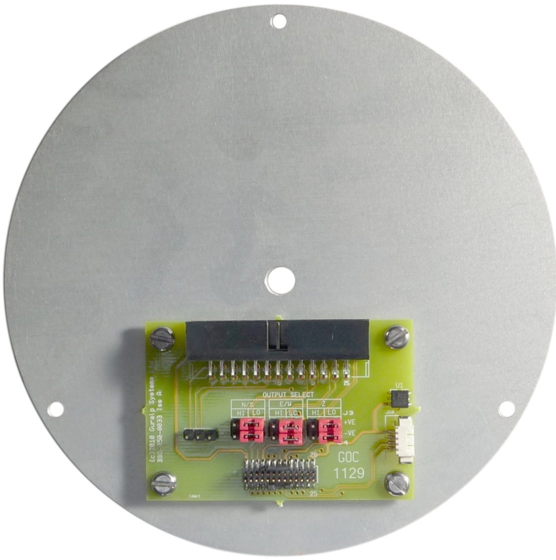
- Note the location of the lid with respect to the body. Use a pencil or adhesive tape to mark both so that the instrument can be reassembled in the correct orientation.

- Using a medium, flat-bladed screwdriver, gently prise the lid away from the body. A slot is provided in the top of the cylinder for this purpose.

> **Note:** The lid-to-body seal uses 'O'-rings. Take care that the lid does not suddenly fly off when this seal is broken.

- Lift the lid and the attached electronics vertically out of the cylindrical body and disconnect the ribbon cable at either end, noting the orientation of the cable.

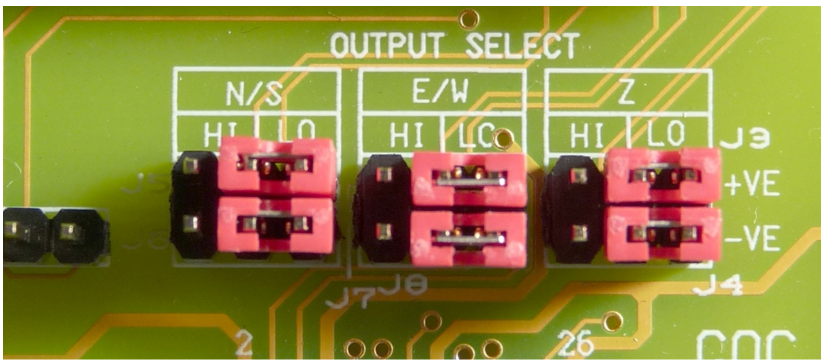
Looking down into the body of the instrument, you will see a small printed circuit board mounted on an aluminium disc. This board contains the gain-setting jumpers, which are coloured red to aid identification.



Each component (vertical, North/South and East/West) has two associated jumpers (one for each leg of the differential connection) and these must always be moved in pairs. It is possible to select different gains for different channels but this is rarely desirable. Consult the markings on the printed circuit board and the pictures below to select the desired gain.

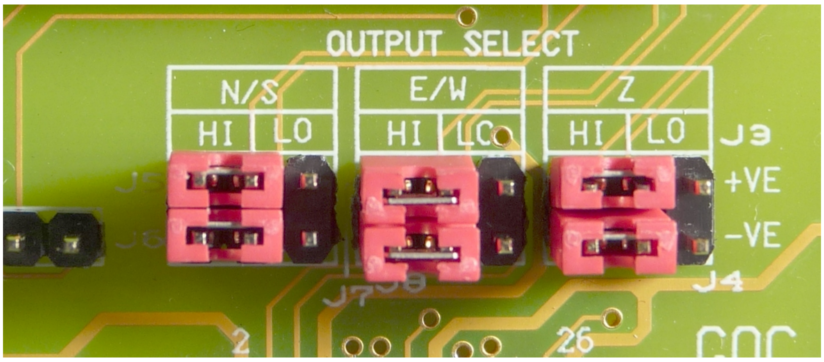
4.2 Jumper configuration for low gain operation

Arrange the jumpers as in the picture below:



4.3 Jumper configuration for high gain operation

Arrange the jumpers as in the picture below:



4.4 Reassembly

Once the desired gain selection has been made, reconnect the ribbon cable and gently lower the lid onto the instrument, taking care not to knock the electronic assemblies or snag any cables. Ensure that the lid is rotated to the correct orientation using the marks you made previously and then gently ease it over the 'O'-ring seal and into place. Secure using the six small screws and, finally, replace the large pressure release screw.

5 Operation

5.1 Installation overview

These steps make up the installation procedure. Detailed instructions follow in subsequent sections.

- Unpack the accelerometer system from the reusable container (See quick start). Save the shipping box for possible future use.
- Prepare the mounting surface.
- Mount the levelling baseplate to the CMG-5TD.
- Orient the CMG-5TD using the orientation pointers.
- Anchor the baseplate to the mounting surface.
- Level the CMG-5TD.
- Install the GPS receiver providing a clear view of the sky, and connect it to the CMG-5TD using the GPS cable.
- Connect the CMG-5TD to a PC running Scream
- Connect the power supply (12 to 36 V DC) to the grey/blue power/data cable
- Switch on the power and view the acceleration time series using Scream.
- Using a DVM, check and adjust the CMG-5TD offsets if required.
- Cover the sensor with a polystyrene cover for long term thermal stability. The cover will act as a thermal shield from draughts. Position the polystyrene box carefully so that it does not touch the sensor package.

5.2 Installation method

The surface should have a scribed north/south orientation line accurately surveyed from reliable markers. Mount the concrete anchor into the mounting bench, around the middle of the orientation line. Loosely attach the mounting (lower) portion of the levelling plate to the concrete anchor, using the bolt provided. Attach the upper portion of the levelling plate to the base of the CMG-5TD using the screws provided. Finally, attach the CMG-5TD to the mounting base by joining the two portions of the levelling plate using the socket-cap screws provided.

5.3 Installation in hazardous environments

The fully enclosed aluminium case design of the 5T instrument makes it suitable for use in hazardous environments where electrical discharges due to the build up of static charge could lead to the ignition of flammable gasses. To ensure safe operation in these conditions, the metal case of the instrument must be electrically bonded ('earthing') to the structure on which it is mounted, forming a path to safely discharge static charge.

Where electrical bonding ('earthing') is required during the installation of a 5T instrument, the central mounting hole that extends through the instrument should be used as the connection point. This is electrically connected to all other parts of the sensor case. Connection can be made either via a cable from a local earthing point terminated in a 8 mm ring tag or via the mounting bolt itself.

5.4 Orientation

Use the handle and north indicator inscribed in the handle to orient the CMG-5TD.

5.5 Levelling

Use the large socket-cap screws to level the CMG-5TD. Remove the upper portion of the mounting plate, then tighten down the concrete bolt, securing the base. Re-attach the upper portion of the mounting plate to the CMG-5TD. Check orientation and level and then tighten down the levelling locking nuts.

5.6 Power supply considerations

The CMG-5TD will operate from 12-36 V DC. The CMG-5TD draws around 185 mA from a 12 V power supply.

5.7 Connections

Connect the GPS receiver to the CMG-5TD using the cables provided.

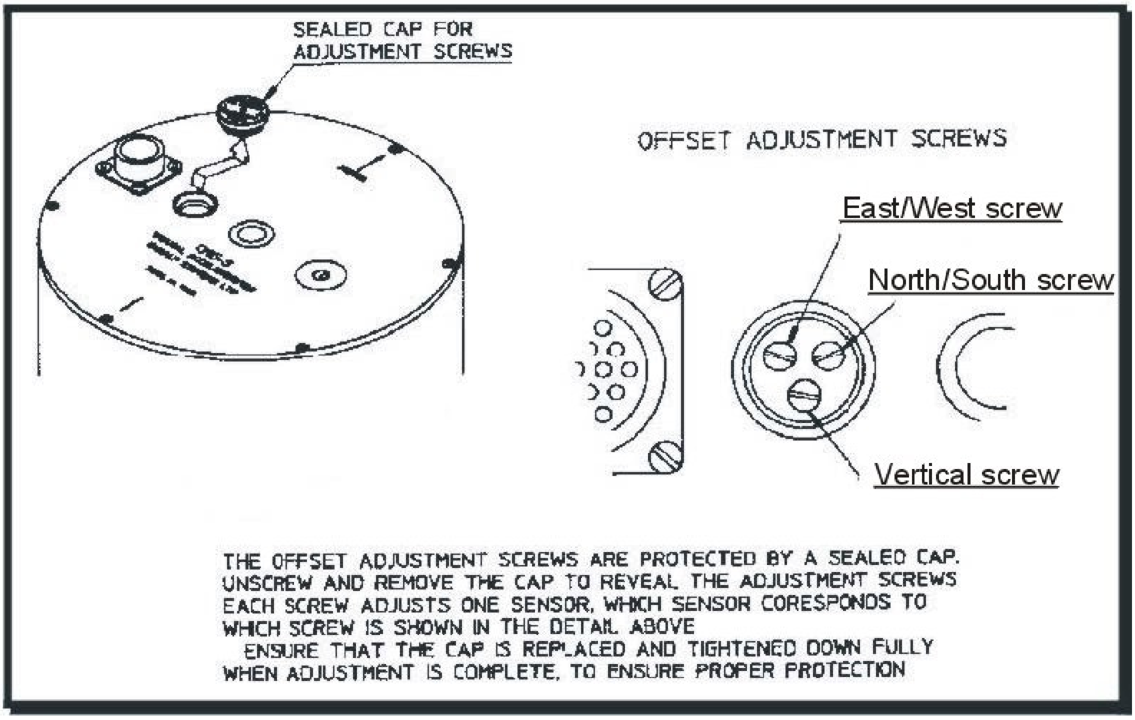
Connect the DE9 connector of the grey/blue power/data cable to a PC or communications device.

Connect the power supply (12 to 36 V DC) to the bare ends of the grey part of the grey/blue power/data cable. The red core should go to the positive terminal or the terminal marked '+' and the black core should go to the negative terminal or the terminal marked '-'. The power supply should be capable of sourcing 200 mA.

5.8 Offset adjustment

When the instrument is installed in it's final position and correctly aligned, the approximate level should be checked using the bubble level on the top of the casing. The bubble should lie completely within the scribed ring. To check the DC offsets, read the RIC value for each acceleration stream in the SCREAM window. No adjustment is necessary if these values are less than or equal to ±5000 counts.

To adjust the DC offsets, remove the screwed cover protecting the adjustment screws, as shown in the diagram below.



Warning: GSL instruments are assembled at near to sea level. When using the instrument at altitude, there may be a considerable pressure differential between the air inside the casing and the external atmosphere. This could cause the sealed cap to fly off with considerable force when initially released. Take care that this does not cause injury.

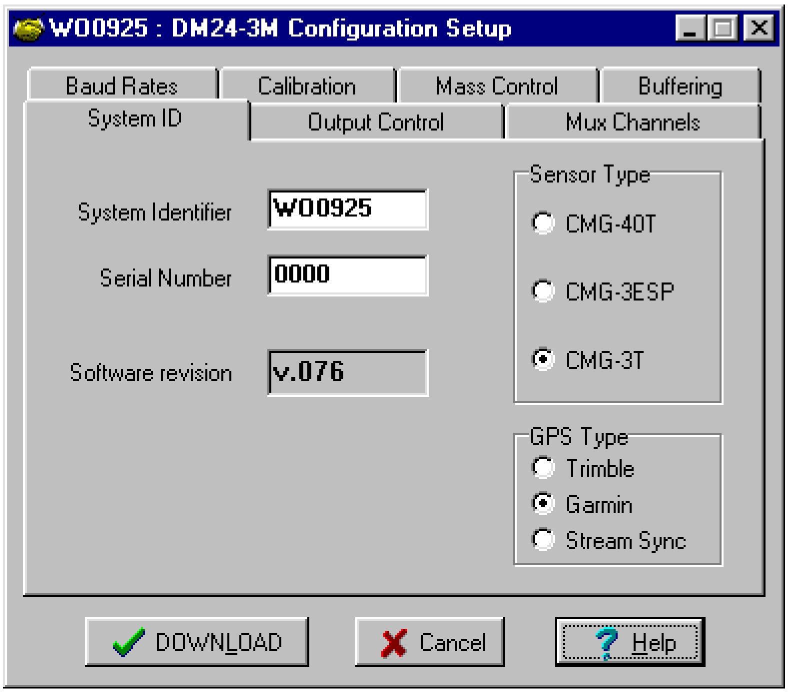
Selecting the channels in turn, adjust the level screws to reduce the RIC values to less than ±5000 counts, repeating until consistent results are obtained on all three channels. When offset adjustment is complete, replace the protective cover firmly.

It is likely that, after the cover is installed, the accelerometer outputs will drift until the system establishes temperature equilibrium with it's environment and the sensor settles down in its position. If required, the adjustment can be repeated to achieve a better (lower) output offset. With experience, it should be possible to reduce low acceleration output levels to about ±5000 counts or less.

5.9 Configuration and control using Scream

Scream is a free software application for Windows and Linux PCs. For more information and download details, please see www.guralp.com/scream/.

The CMG-5TD may be configured using Scream's graphical interface. Right-click on the digitiser's icon in the source tree and select “Configure” from the pop-up menu. Using this dialogue, you may interactively set the digitiser's system characteristics, control the output of streams at different digitisation rates and set output baud rates and digitiser buffering parameters.



Alternatively, using terminal emulation software, such as PuTTY, minicom or Hyper Term, you can access the digitiser's command line and send commands directly to the built in CMG-DM24 digitiser.

This mode may also be invoked from Scream by right-clicking on the digitiser's icon and selecting Terminal from the pop-up menu. When using standard terminal programs, you must initiate command mode by typing Ctrl + S. This is done automatically by Scream when a terminal window is opened to a digitiser. If you use the Scream configuration dialogue, data collection will continue while you are setting digitiser parameters. If you use Scream's terminal mode or a terminal emulator, data collection will be interrupted until you exit terminal mode by typing “GO” or issuing a RE-BOOT command.

Parameters from most of the commands are stored to the battery-backed CMOS and only take effect when the digitiser is rebooted. When you click the “Download” button from the digitiser configuration interface, the parameters you have chosen are transferred to the digitiser and it is automatically rebooted. You will notice a data gap in the traces in the Waveview window corresponding to the digitiser you have rebooted. This occurs because the reboot automatically clears the data buffer and resets the output block counter.

To access the digitiser configuration dialogue from Scream, double-click on the digitiser's icon in the Available Streams window (NOT the Local or COM port icons). Alternatively, you can right-click on the digitiser's icon and then select “Configure” from the pop-up menu.

The following sections correspond to the different tabs available in the configuration dialogue.

5.9.1 System ID

System Identifier and Serial Number: The digitiser type is identified by its system identifier and serial number. These two parameters are stored as the first two 32-bit fields in the header of each data and status block generated by the digitiser, in order to indicate the block's origin. Each of these parameters consists of 6 alphanumerics encoded as base 36 numbers. On delivery from the factory, the system identifier and the serial number are, respectively, set to the GSL works order number and the seismometer’s serial number. Either parameter can be reset to any convenient combination of letters and numbers, such as an abbreviation of your institution and the deployment site code.

Sensor Type: This field will be pre-programmed at the factory for the proper sensor type (CMG-5T).

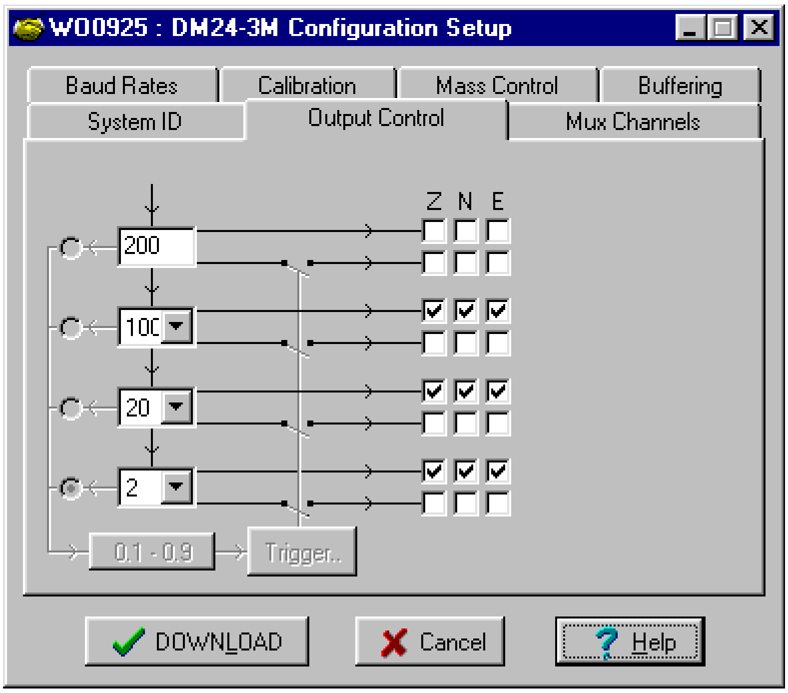
GPS Type: The digitiser can utilize time signals from different sources. Options available are NMEA (Garmin or Trimble) GPS receivers or stream synchronization. When using stream synchronization, time signals from a GPS antenna are sent via telemetry from a central site to the digitiser. In order to synchronize with the time standard in use, the correct option must be selected.

5.9.2 Output control

Sampling rate: The output of the digitiser’s analogue-to-digital converters (ADC) is sampled at 2 kHz. These data are filtered and reduced to lower rates using a digital signal processor (DSP). The DSP has four cascaded filter/decimation stages, each of which can be programmed for decimation factors of ÷2, ÷4, ÷5, ÷8 or ÷10. The output of each stage is called a “tap”. Each stage may be configured for a different decimation factor.

The four text-fields on the left of the Output Control tab allow you to select the sampling rates for each of the four digitiser taps. Each of the taps must have a sampling rate lower than the one above but the rate must be achievable using decimation by a factor of 2, 4, 5, 8 or 10. Each drop-down menu offers a list of the rates that are permitted, given the sampling rate on the line above it.

If some of the outputs are not required, leave the check-boxes clear in order to reduce communications bandwidth requirements.



Stream selection: The digitiser has three channels or streams. These are depicted by the three columns labelled Z, N and E in the Output Control window shown above.

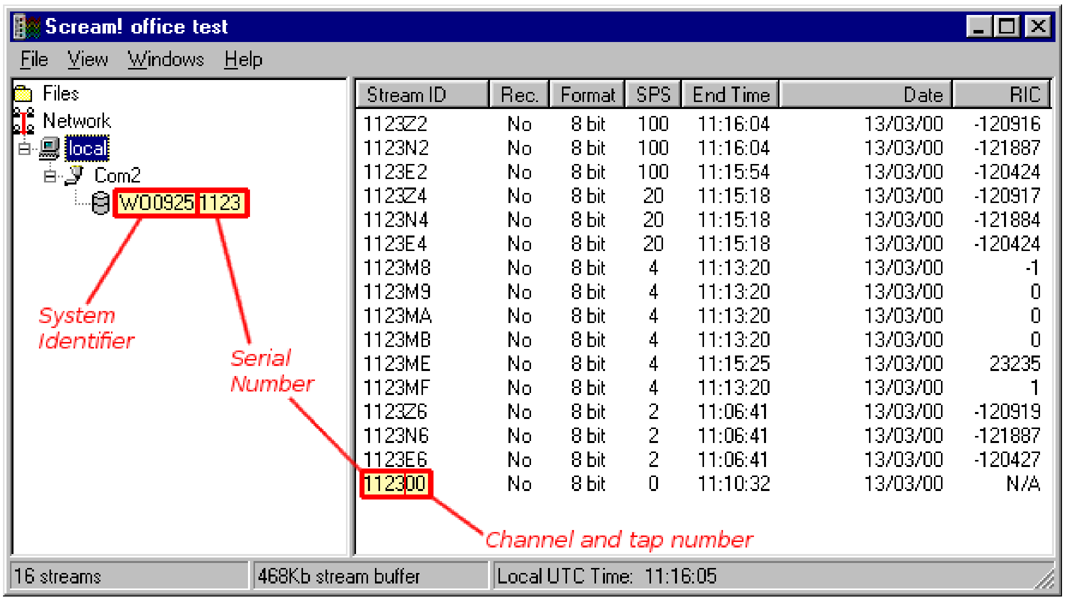
A tick in a box will give an output for the corresponding channel (column) at the corresponding sample rate (row). For each sample rate there are two possible rows to tick. The upper row for each sample rate will give a continuous output at that sample rate; the lower row, shown diagrammatically as passing through a switch, will only output data when its trigger criteria are met (see below).

The Stream IDs displayed in the main Available Streams window have six-character ID's. The first four characters identify the digitiser and the last two characters identify the stream from the digitiser. The first of these two characters identify the channel, while the second defines the 'tap', or digitiser output (see Data Transmission Protocol & Data Block Structure later).

For example; for the Output Control configuration shown above, there will be three data streams, Z, N and E, providing continuous data at 100sps, 20sps and 2sps. This is shown below, where the digitiser '1123' has the following streams:-

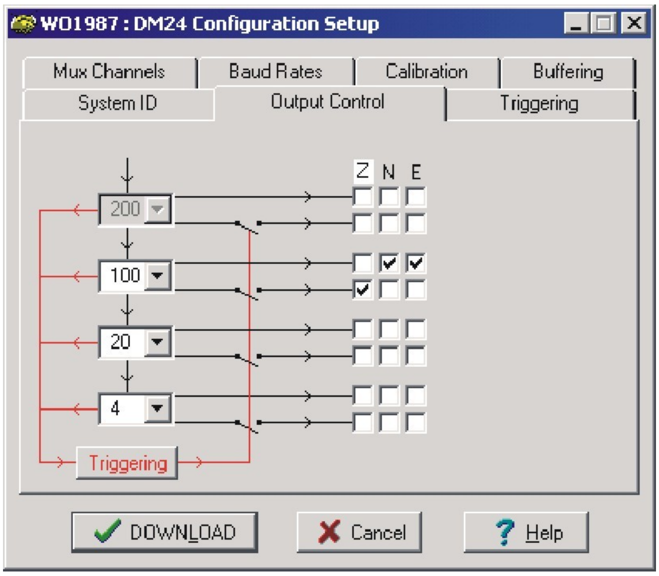
- Z2, N2, E2 are input channels Z, N, E output through the second tap ‘2’;
- Z4, N4, E4 are input channels Z, N, E output through the third tap ‘4’,
- Z6, N6, E6 are input channels Z, N, E output through the fourth tap ‘6’,
- 00 is the digitiser status stream (notice that there is no sample rate)

(Odd tap numbers (1, 3, 5, …) are used for streams from a second instrument.)



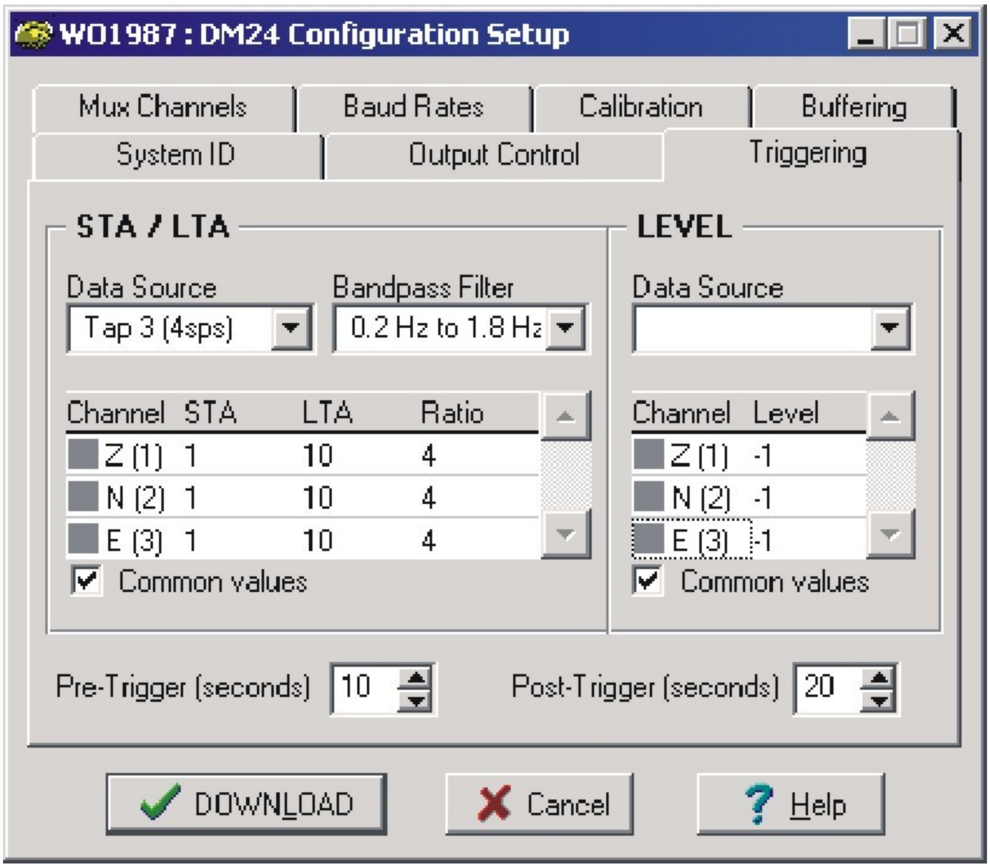
For each tap there are two rows of check-boxes where the user can tick either triggered or continuous data outputs. The digitiser applies a simple short term average (STA) ÷ long term average (LTA) algorithm and/or an absolute level (counts) algorithm to a selected stream or set of streams to determine whether the trigger condition is met. These streams may be bandpass filtered before evaluation using standard bandpass parameters. The data transmitted due to the trigger may be from different streams than those used to determine the trigger.

For this to function properly, triggering streams must be selected and trigger criteria must be set by clicking on the Trigger button . When at least one stream is selected for triggered output, selection of triggering streams and trigger criteria are enabled. It is possible to trigger from one tap but record data from one or several different taps.



5.9.3 Triggering

Once at least one box is checked for triggered output, the Triggering box and tab are activated. If you set triggering, you must also set the parameters for the trigger criteria.



The Data Source button selects the tap (streams) that will be evaluated for triggers for both the STA/LTA and the Level triggers. In general, it is not advisable to use an STA/LTA trigger directly from broadband data. The Bandpass Filter button allows the user to select from a set of standard bandpass filters from a pull-down menu (a full list of options is given later in the STA/LTA chapter). The chosen filter will be applied to the streams from the triggering components before they are tested for the trigger condition.

The corner frequencies of the pass band of the filter are determined by the Nyquist frequency, which is given by the sampling rate of the triggering data. The three filter options have pass bands between 10% and 90%, between 20% and 90% and between 50% and 90% of the data's Nyquist frequency, respectively.

Trigger criteria: Trigger criteria for the STA/LTA and Level triggers function may be set in the Trigger Setup window, accessed by clicking on the Trigger button near the bottom of the Output Control window.

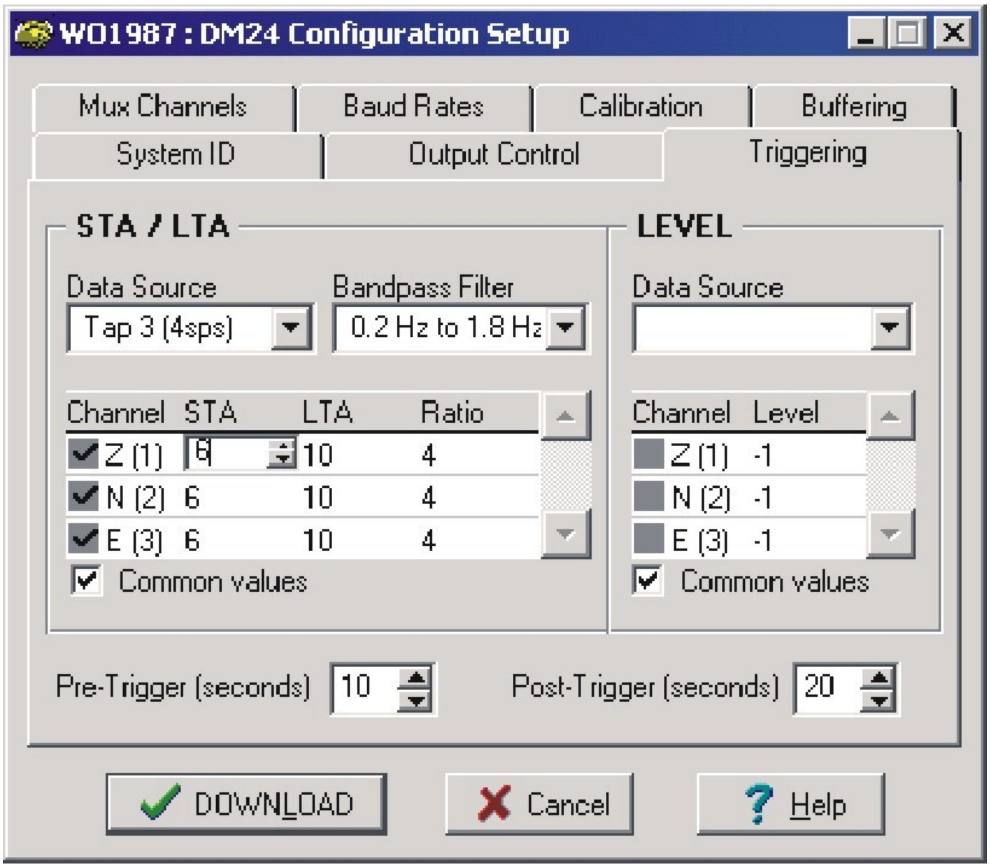
The three tick boxes down the left side of the windows (Z, N, E) allows the user to choose the channels (for the specified tap) which will be tested for a trigger condition.

STA/LTA parameters: The user sets the parameters by clicking on them. Typically, the time interval for the short term average should be about as long as the signals you want to trigger on, while the long term average should be taken over a much longer interval. Both the STA and LTA values are recalculated continually, even during a trigger.

The system declares a trigger when any one of the triggering components exceeds this value. The trigger ratio is continuously recalculated for all components and the system will only cancel the trigger condition when all the components selected for triggering have fallen below their respective ratio values.

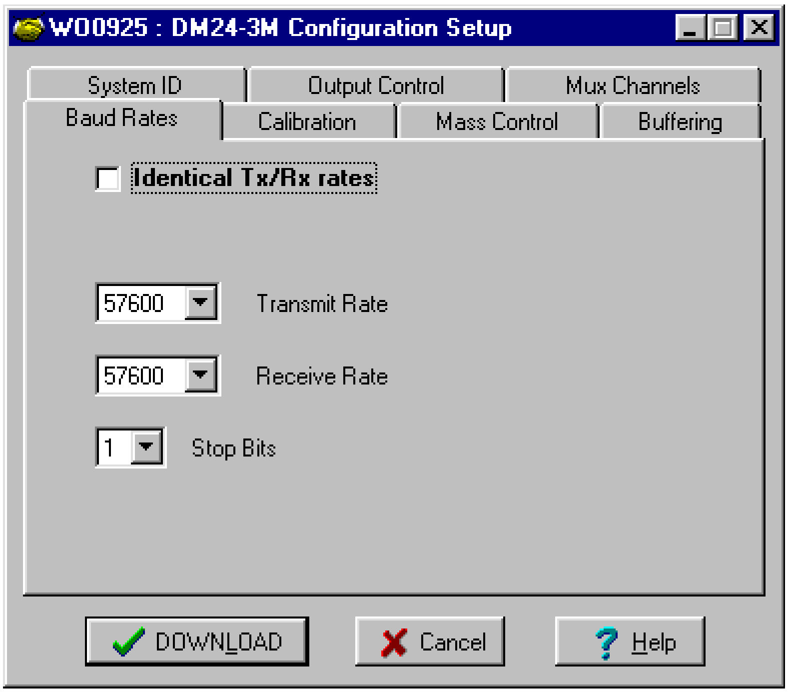
The user can also specify the pre-trigger and post-trigger data intervals. These values determine the minimum length of data that will be saved prior to the trigger condition, and how much data will be saved after the trigger condition has lapsed. Triggered streams will always start and end on integer seconds.

If the box "Common Values" is ticked, a trigger parameter entered for one component will be used for all selected components. (BANDPASS, STA, LTA, RATIO, PRE-TRIG and POST-TRIG).



Level triggering parameters: The user specifies the Data Source, channels and levels by clicking on them, similar to the STA/LTA settings. The levels are specified in counts.

5.9.4 Baud rates



This tab allows the setting of the line speed for the main serial output.

It is possible to set different rates for transmission and reception but this is rarely required with modern communications equipment. Ticking the "Identical Tx/Rx rates" check-box simplifies the dialogue.

A line speed of 115,200 Baud is adequate for the highest sample rates that the instrument can generate. It may be necessary to reduce the line speed if the data are to be passed over a modem or wireless link.

The "Stop Bits" drop-down menu should be left at 1 unless your communications equipment requires a different value.

5.9.5 Data flow

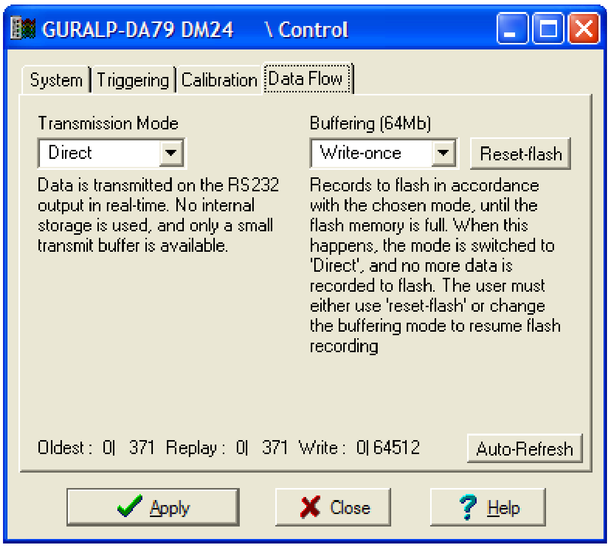
The digitizer operates in one of several *transmission modes*. These modes relate to how the unit uses its Flash memory:

- as a simple data store, from which you can request data (*FILING* and *DUAL* modes);
- as a buffer holding unacknowledged blocks, which are transmitted in preference to real-time data (*FIFO* mode);
- as a buffer holding unacknowledged blocks, which are transmitted whenever the transmission is free but no real-time data blocks are ready (*ADAPTIVE* mode);
- not at all (*DIRECT* mode).

Separate from these modes are *buffering modes*, which tell the unit what to do when its Flash memory becomes full: either

- carry on, overwriting the oldest data held, or
- stop writing and switch the digitizer into *DIRECT* mode.

You can switch between filing modes in Scream! by right-clicking on the digitizer and clicking on **Control...**, then navigating to the **Data Flow** pane:



To choose a transmission or buffering mode, choose options from the *Transmission Mode* or *Buffering* drop-down menus, and click **Apply**. An explanation of the chosen mode is displayed beneath each menu. The following sections also explain the filing modes available.

The *Buffering* legend also displays the amount of Flash memory present in your digitizer. In the example screen-shot above, this is 64 Mb.

To clear the Flash memory of the digitizer, click the **Reset-flash** button. You will be asked for confirmation before the memory is cleared.

At the bottom of the tab is a line describing the current state of the digitizer's memory pointers. You can use this line to check that data are being written into memory. Select **Auto-Refresh** to make the line update automatically.

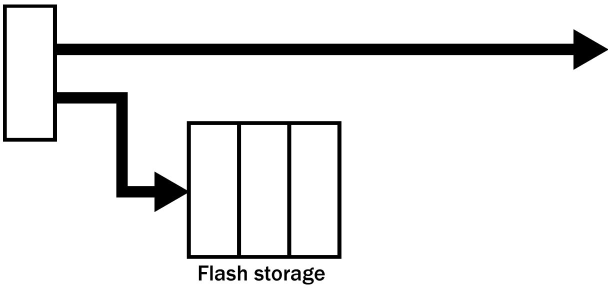
5.9.5.1 DIRECT

Instructs the digitizer not to use Flash memory for storage. Instead, all data are transmitted directly to clients. An instrument in *DIRECT* mode still honours the GCF Block Recovery Protocol: a temporary RAM buffer always holds the last 256 blocks generated, and if a client fails to receive a block it can request its retransmission.

If you expect breaks in communication between the instrument and its client to last more than 256 blocks, or if you want the instrument to handle breaks in transmission (rather than relying on the client to request missed blocks), you should use

- *ADAPTIVE* mode, if you want data to stay as near to real time as possible (but do not mind if blocks are received out of order) or
- *FIFO* mode, if you need blocks to be received in strict order (but do not mind if the instrument takes a while to catch up to real time.)

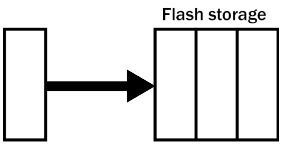
5.9.5.2 DUPLICATE



Instructs the DM24 to transmit streams directly to clients as for DIRECT mode, but also to store all data into Flash storage as for FILING mode. If a client fails to acknowledge a block, the digitizer does not attempt to retransmit it.

Heartbeat messages are not sent in DUPLICATE mode.

5.9.5.3 FILING



Instructs the digitizer not to transmit blocks to clients automatically, but to store all digitized data in the Flash memory. If you have chosen the *RECYCLE* buffering mode (see below), the memory is used in circular fashion, *i.e.* if it becomes full, incoming blocks begin overwriting the oldest in memory. If the *WRITE-ONCE* mode is active, the instrument will switch to *DIRECT* mode (see above) when the memory becomes full.

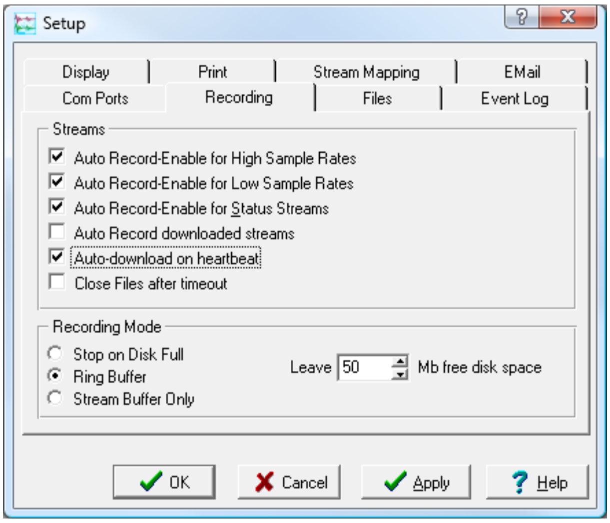
Heartbeat messages

When in *FILING* mode, an instrument transmits “heartbeat” messages over its data port. These short messages take the place of data blocks, and ensure that programs such as Scream! know that an instrument is present.

If your digitizer is in *FILING* mode, Scream! will displays a slider at the bottom of the tab. Moving this slider changes the interval between heartbeat blocks.

You can tell Scream! to download new data automatically whenever it receives a heartbeat message from an instrument in *FILING* mode. This is useful, for example, in autonomous installations connected by intermittent modem links. To enable this feature:

1. Choose **File → Setup…** from Scream!'s main menu, and navigate to the *Recording* pane.

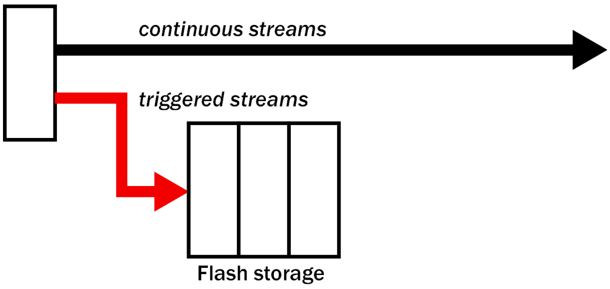


2. Check *Auto-download on heartbeat*.

3. Click **OK**.

Using *FILING* mode with *Auto-download on heartbeat* ensures that Scream! receives all new data whenever it can, regardless of the configuration of any devices between you and the instrument.

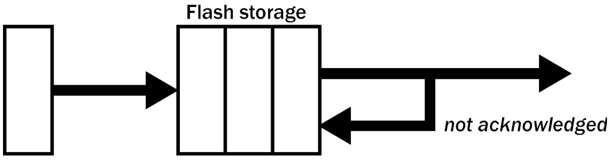
5.9.5.4 DUAL



Instructs the digitizer to transmit any *continuous* streams directly to clients as for *DIRECT* mode, but to store *triggered* data into Flash storage as for *FILING* mode.

If you choose *DUAL* mode but do not select any continuous streams for output, the instrument will send heartbeat messages as for *FILING* mode. Scream! can pick these up and download new data as necessary.

5.9.5.5 FIFO (First In First Out)



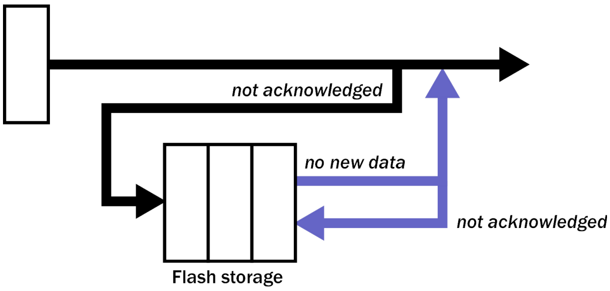
Instructs the digitizer to begin writing blocks to Flash memory as for *FILING* mode, but also to transmit data to clients. Data are transmitted in strict order, oldest first; the digitizer will only transmit the next block when it receives an explicit acknowledgement of the previous block.

If the communications link is only marginally faster than the data rate, it will take some time to catch up with the real-time data after an outage. If you want data to be transmitted in real-time where possible, but are worried about possible breaks in communication, you should use *ADAPTIVE* mode instead.

FIFO mode will consider a data block successfully transmitted once it has received an acknowledgement from the next device in the chain. If there are several devices between you and the instrument, you will need to set up the filing mode for each device (if applicable) to ensure that data flow works the way you expect.

Like all the filing modes, *FIFO* mode does not delete data once they have been transmitted. You can still request anything in the Flash memory using Scream! or over the command line. The only way data can be deleted is if they are overwritten (in the *RECYCLE* buffering mode, see below) or if you delete them manually.

5.9.5.6 ADAPTIVE



Instructs the digitizer to transmit current blocks to clients if possible, but to store all unacknowledged blocks in the Flash memory and re-send them, oldest first, when time allows. *ADAPTIVE* mode is best suited for "real-time" installations where the link between digitizer and client is intermittent or difficult of access.

If the communications link is only marginally faster than the data rate, it will usually be busy transmitting real-time data. Thus, it may take a while for the instrument to work through the missed blocks. In this case, and if your client supports it, you may prefer to use the Block Recovery Protocol to request missed blocks where possible.

Some software packages (most commonly Earthworm) cannot handle blocks being received out of time order. If you are using such a package, *ADAPTIVE* mode will not work, and may crash the software.

5.9.6 Buffer Memory Usage

5.9.6.1 RE-USE / RECYCLE

Instructs the digitizer to carry on using the current filing technique when the Flash memory becomes full, overwriting the oldest data held. This buffering mode is called *RECYCLE* in Scream!

For example, in *DUAL* mode with *RECYCLE* buffering, the latest continuous data will be transmitted to you as normal, and the latest triggered data may be retrieved from the Flash memory using Scream! or the digitiser's command line. However, if you do not download data regularly from the Flash memory, you may lose older blocks. This mode thus lets you define the end point of the data held by the instrument.

5.9.6.2 WRITE-ONCE

Instructs the digitizer to stop writing data to the Flash memory when it is full, and to switch to *DIRECT* mode automatically.

For example, in *FIFO* mode with *WRITE-ONCE* buffering, the station will transmit data to you continuously, but also save them in the Flash memory until it is full. Once full, the instrument will switch to *DIRECT* mode and continue transmitting, though no further data will be saved. This mode thus lets you define the start point of the data held by the instrument.

6 Calibration

6.1 The calibration pack

All Güralp sensors are fully calibrated before they leave the factory. Both absolute and relative calibration calculations are carried out. The results are given in the calibration pack supplied with each instrument:

Works Order : The Güralp factory order number including the instrument, used internally to file details of the sensor's manufacture.

Serial Number : The serial number of the instrument

Date : The date the instrument was tested at the factory.

Tested By : The name of the testing engineer.

There follows a table showing important calibration information for he instrument, which shows:

Acceleration Output (Differential) : The sensitivity to acceleration at 1 Hz, in volts per ms^{-2}. Because the CMG-5TD uses a balanced differential output to connect to the digitiser, the signal strength as measured between the +ve and –ve line will be twice the true sensitivity of the instrument. To remind you of this, the sensitivity is given as 2 × (single-ended sensitivity).

Feedback Coil Constant : A constant describing the characteristics of the feedback system. You will need this constant, given in amperes per ms^{-2}, if you want to perform your own calibration calculations (see below.)

Power Consumption : The average power consumption of the sensor during testing, given in amperes and assuming a 12 V supply.

Calibration Resistor : The value of the resistor in the calibration circuit. You will need this value if you want to perform your own calibration calculations (see below.)

6.1.1 Poles and zeroes

Most users of seismometers find it convenient to consider the sensor as a “black box”, which produces an output signal V from a measured input x. So long as the relationship between V and x is known, the details of the internal mechanics and electronics can be disregarded. This relationship, given in terms of the Laplace variable s, takes the form

$$(V / x) (s) = G \times A \times H (s)$$

In this equation

- *G* is the acceleration output sensitivity (gain constant) of the instrument. This relates the actual output to the desired input over the flat portion of the frequency response.
- *A* is a constant which is evaluated so that $A \times H(s)$ is dimensionless and has a value of 1 over the flat portion of the frequency response. In practice, it is possible to design a system transfer function with a very wide-range flat frequency response.

  The normalising constant *A* is calculated at a normalising frequency value *f*m = 1 Hz, with $s = j\,f\text{m}$, where $j = \sqrt{-1}$.
- *H* (*s*) is the transfer function of the sensor, which can be expressed in factored form:

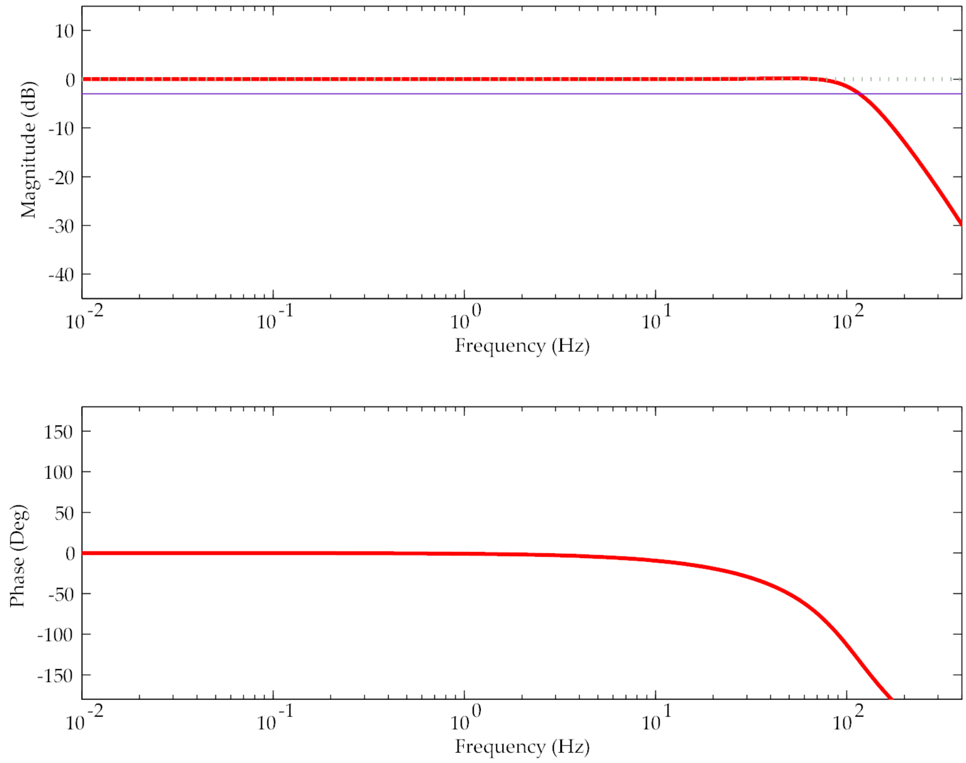
$$H(s) = N \frac{\prod_{i=1,n} s - Z_i}{\prod_{j=1,m} s - P_j}$$

  In this equation, z_n are the roots of the numerator polynomial, giving the zeros of the transfer function, and p_m are the roots of the denominator polynomial giving the poles of the transfer function.

In the calibration pack, *G* is the sensitivity given on the first page, whilst the roots z_n and p_m, together with the normalising factor *A*, are given in the *Poles and Zeros* table. The poles and zeros given are measured directly at Güralp Systems' factory using a spectrum analyser.

6.1.2 Frequency response curves

The frequency response of the CG-5TD is described in the normalised amplitude and phase plots provided. The response is measured at low and high frequencies in two separate experiments. Each plot marks the low-frequency and high-frequency cut-off values (also known as –3 dB or half-power points).



If you want to repeat the calibration to obtain more precise values at a particular frequency of interest, or to check that a sensor is still functioning correctly, you can inject calibration signals into the system using a Güralp digitizer or your own signal generator, and record the instrument's response.

6.1.3 Obtaining copies of the calibration pack

Our servers keep copies of all calibration data that we send out. In the event that the calibration information becomes separated from the instrument, you can obtain all the information using our free e-mail service. Simply e-mail `caldoc@guralp.com` with the serial number of the instrument in the subject line, *e.g.*

```
From: your@email.net
To: caldoc@guralp.com
Subject: T5215
```

The server will reply with the calibration documentation in Microsoft Word format. The body of your e-mail will be ignored.

6.2 Calibration methods

Three common calibration techniques are available:

- Injecting a step current allows the system response to be determined in the time domain. The amplitude and phase response can then be calculated using a Fourier transform. Because the input signal has predominantly low-frequency components, this method generally gives poor results. However, it is simple enough to be performed daily.

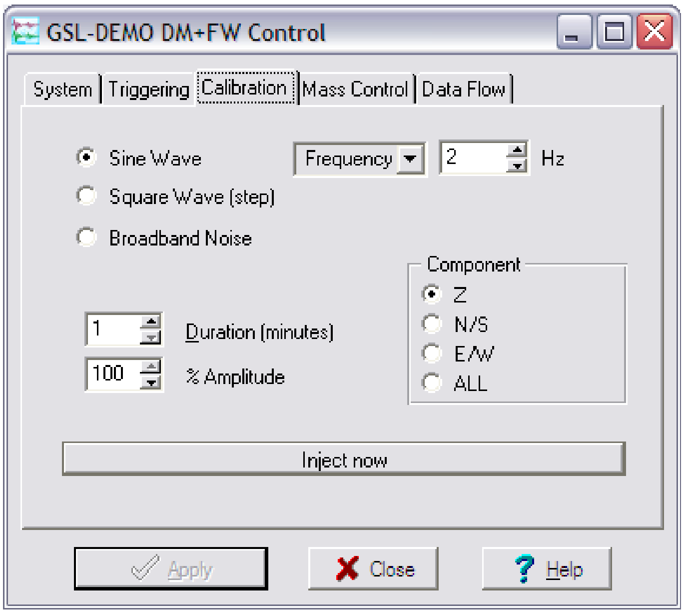
- Injecting a sinusoidal current of known amplitude and frequency allows the system response to be determined at a spot frequency. However, before the calibration measurement can be made, the system must be allowed to reach a steady state; for low frequencies, this may take a long time. In addition, several measurements must be made to determine the response over the full frequency spectrum.
- Injecting white noise into the calibration coil gives the response of the whole system, which can be measured using a spectrum analyser.

You can perform calibration using the built-in CMG-DM24 digitizer, which can generate step and sinusoidal calibration signals.

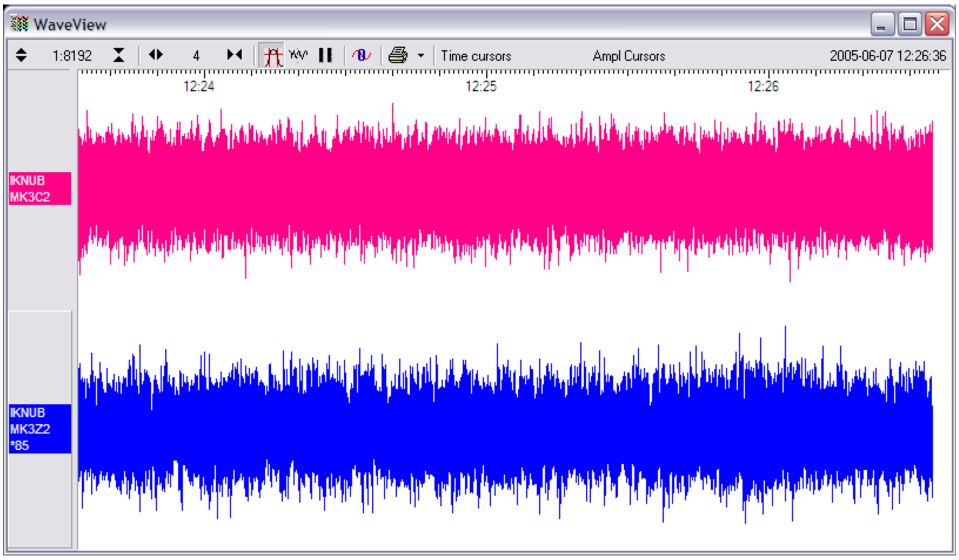
6.3 Calibration with Scream!

Calibration is most easily done using a PC running Güralp's Scream! Software. In this section, broadband noise calibration will be used to determine the complete sensor response in one action. Please refer to the CMG-DM24 and Scream manuals for information on other calibration methods.

1. In Scream!'s main window, right-click on the digitiser's icon and select **Control…**. Open the *Calibration* pane.



2. Select the calibration channel corresponding to the instrument, and choose **Broadband Noise.** Select a suitable duration and amplitude, and click **Inject now**. A new data stream, ending `C`<u>n</u> (<u>n</u> = 0 – 7) or `MB`, should appear in Scream!'s main window containing the returned calibration signal.



3. Open a Waveview window on the calibration signal and the returned streams by selecting them and double-clicking. The streams should display the calibration signal combined with the sensors' own measurements. If you cannot see the calibration signal, zoom into the Waveview using the scaling icons at the top left of the window or the cursor keys.

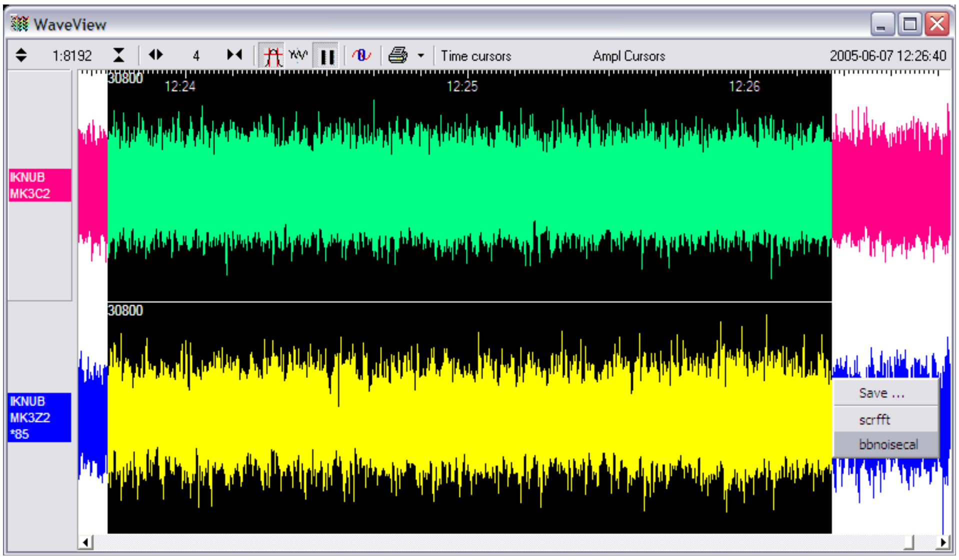
   Drag the calibration stream `Cn` across the Waveview window, so that it is at the top.

4. If the returning signal is saturated, retry using a calibration signal with lower amplitude, until the entire curve is visible in the Waveview window.

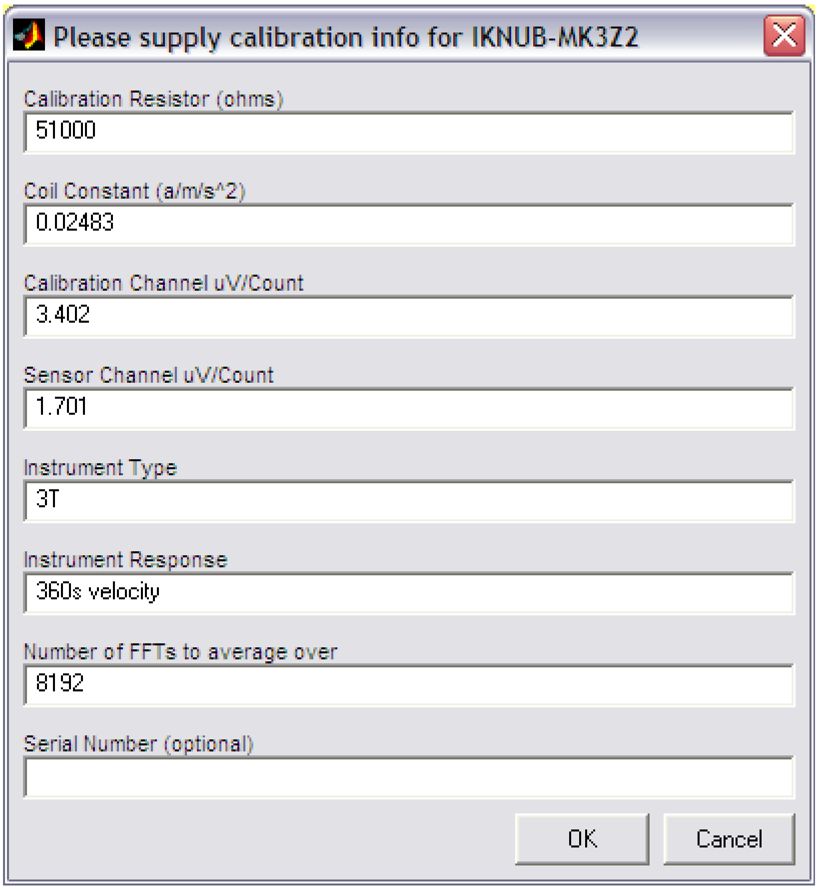
5. If you need to scale one, but not another, of the traces, right-click on the trace and select **Scale...**. You can then type in a suitable scale factor for that trace.

6. Pause the Waveview window by clicking on the  icon.

7. Hold down SHIFT and drag across the window to select the calibration signal and the returning component(s). Release the mouse button, keeping SHIFT held down. A menu will pop up. Choose **Broadband Noise Calibration.**



8. This runs a script, bbnoisecal, which prompts you for sensor calibration parameters for each component you have selected.

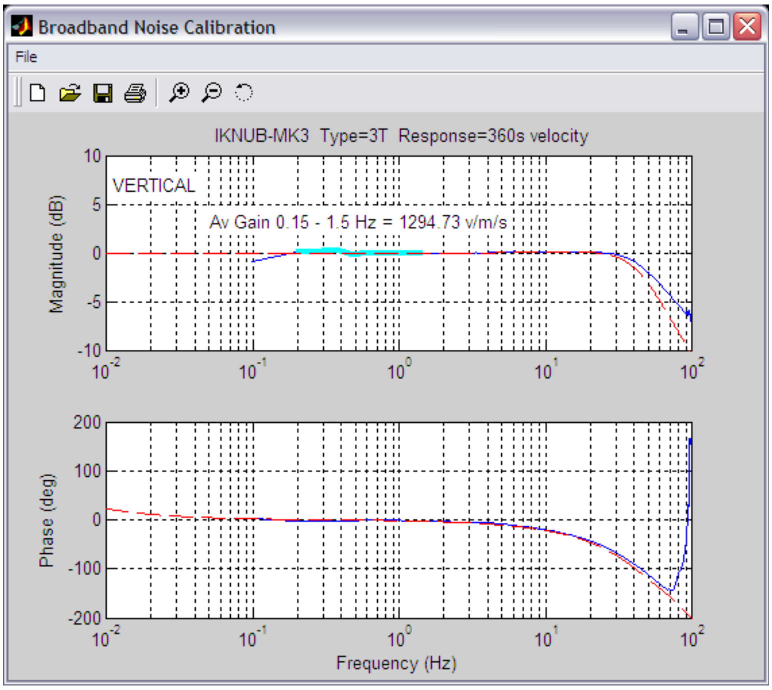


9. Most data can be found on the calibration sheet for your sensor. Under *Instrument response*, you should fill in the sensor response code for your sensor, according to the table below. *Instrument Type* should be set to the model number of the sensor.

10. If the file `calvals.txt` exists in the same directory as Scream!'s executable (`scream.exe`), Scream! will look there for suitable calibration values. A sample `calvals.txt` is supplied with Scream!, which you can edit to your requirements. Each stream has its own section in the file, headed by the line `[`***`instrument-id`***`]`. The ***`instrument-id`*** is the string which identifies the digitizer in the left-hand pane, *e.g.* `GURALP-DEMO`. It is always 6 characters or fewer (the system identifier) followed by a dash, then 4 characters or fewer (the serial number). For example:

```
[DEMO00-4V99]
Serial-Nos=T4V99
VPC=3.153
G=1010
COILCONST=0.02575
CALVPC=3.161
CALRES=51000
TYPE=sensor-type
RESPONSE=response-code
```

11. Click `OK`. The script will return with a graph showing the response of the sensor in terms of amplitude and phase plots for each component.



The accuracy of the results depends on both the amount of data you have selected and on its sample rate. To obtain good-quality results at low frequency, it will save computation time to use data collected at a lower sample rate; although the same information is present in higher-rate streams, they also include a large amount of high-frequency data which may not be relevant to your purposes.

The `bbnoisecal` script automatically performs appropriate averaging to reduce the effects of aliasing and cultural noise.

6.3.1 Sensor response codes

The table below shows the correct value to use in the *Instrument response* field of the **`bbnoisecal`** dialogue, depending on the type of your instrument.

Sensor	**Sensor type code**	**Units (V/A)**
CMG-5TD, DC – 50 Hz response	`DC-50`	`A`
CMG-5TD, DC – 100 Hz response	`CMG-5_100`	`A`
CMG-5TD, DC – 200 Hz response	`CMG-5_200`	`A`

7 Connector pin-outs

7.1 DATA

This is a standard 10-pin "mil-spec" plug, conforming to MIL-DTL-26482 (formerly MIL-C-26482). A typical part-number is 02E-12-10P although the initial "02E" varies with manufacturer.

Suitable mating connectors have part-numbers like ***-12-10S and are available from Amphenol, ITT Cannon and other manufacturers.

The pin-out is the same as the serial output of a CMG-DM24 digitiser and any GSL digital instrument, allowing you to insert an instrument with an embedded CMG-EAM into a pre-existing installation and maintain connectivity.

Pin	Function
A	Power input, 0 V
B	Power input, +10 to +35 V
C	RS232 CTS
D	RS232 RTS
E	*Not connected*
F	*Not connected*
G	RS232 ground
H	*Not connected*
J	RS232 receive
K	RS232 transmit

Wiring details for the compatible socket, ***-12-10S, as seen from the cable end (i.e. during assembly).

7.2 GPS

This is a standard 10-pin "mil-spec" plug, conforming to MIL-DTL-26482 (formerly MIL-C-26482). A typical part-number is 02E-12-10P although the initial "02E" varies with manufacturer.

Suitable mating connectors have part-numbers like ***-12-10S and are available from Amphenol, ITT Cannon and other manufacturers.

This pin-out is the same as the GPS input of a DM24 digitizer.

Pin	Function
A	Power 0 V
B	Power +12 V
C	1pps signal
D	*not connected*
E	Console TxD
F	Console RxD
G	GPS ground
H	Console ground
J	RS232 transmit to GPS
K	RS232 receive from GPS

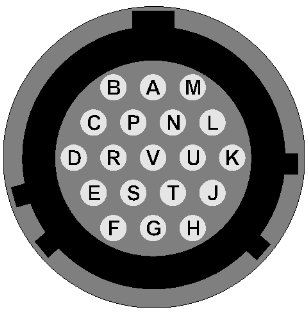
Wiring details for the compatible socket, ***-12-10S, as seen from the cable end (i.e. during assembly).

7.3 Analogue connector

This is a standard 19-pin “mil-spec” socket, conforming to MIL-DTL-26482 (formerly MIL-C-26482). A typical part-number is 02E-14-19S although the initial “02E” varies with manufacturer.

Suitable mating connectors have part-numbers like ***-14-19P and are available from Amphenol, ITT Cannon and other manufacturers.

Pin	Function	Pin	Function
A	High-gain N/S acc non-inverting	L	Unity-gain Z acc inverting
B	High-gain N/S acc inverting	M	Unity-gain Z acc non-inverting
C	Unity-gain N/S acc non-inverting	N	High-gain Z acc inverting
D	Unity-gain N/S acc inverting	P	High-gain Z acc non-inverting
E	Calibration signal	R	High-gain E/W acc non-inverting
F	Power +12 V	S	Calibration enable
G	Power 0 V	T	Signal ground
H	not connected	U	Unity-gain E/W acc non-inverting
J	Open/Closed loop mode	V	High-gain E/W acc inverting
K	Unity-gain E/W acc inverting		



Wiring details for the compatible plug, ***-14-19P, as seen from the cable end (*i.e.* when assembling).

8 Specifications

Transducer type	Accelerometer
Standard output band	DC – 100 Hz
Output sensitivity	4 g, 2 g, 1 g, 0.5 g, 0.1 g
Corresponding high gain outputs	0.4 g, 0.2 g, 0.1 g 0.05 g, 0.01 g
Peak analogue output	±10 V differential
Analogue output impedance	47 Ω nominal
Lowest spurious resonance	> 450 Hz
Linearity	0.1 % full scale
Cross-axis rejection	0.001 g/g
Dynamic range	> 165 dB > 140 dB for 0.005 – 0.05 Hz > 127 dB for 3 – 30 Hz
Operating temperature	–20 to +70 °C
Materials	Hard anodized aluminium case Mil-spec connectors
Case diameter	176 mm
Case height (with feet / handle)	245 mm
Case height (sensor only	160 mm
Weight	4.3 kg
Isolating power supply	12 – 28 V DC
Current at 12 V DC	185 mA
Calibration controls	Command-line
Optional low pass corner	50, 100 or 200 Hz

9 Revision History

A	2002-06-05	Initial release
B	2002-10-21	Revision for firmware updates
C	2003-01-22	Revision for firmware updates
D	2012-04-17	Reformatted and revised